DO THE MINING OPERATIONS AFFECT THE CLIMATE OF KIMBERLEY?

By J. R. Sutton.

(Read October 27, 1898.)

In essentials diamond-mining differs little from any other enterprise whose object is to obtain possession of minerals lying at any depth beneath the surface of the earth. Shafts have to be sunk, and tunnels driven, and the diamond-bearing rock ("Kimberlite" or "blue-ground") has to be excavated and hauled to the surface for treatment before its wealth can be proved, in much the same way as though the quest were gold or iron. But diamond-mining differs from most other extensive mining operations in this: that Kimberlite being for the most part easily pulverable by ordinary atmospheric influences continued long enough, is more advantageously and cheaply treated by spreading it, as soon as it leaves the mine, over the ground, where sun and rain can act freely upon it and disintegrate it, than it would be by crushing, or by any other process having the same objects. The depositing sites for blue-ground fresh from the mines are known as *Floors*. The floors belonging to the De Beers and Kimberley Mines extend, practically without interruption, some four miles east and west, and from one to two miles north and south; and in order that they shall be as convenient as possible they are cleared of every trace of vegetation—trees, bushes, and grass all being sacrificed. The blue-ground is spread upon the floors to an average depth of about 10 inches, and remains there for a period which may run into many months until it is sufficiently disintegrated to be ready for washing and sorting. It is seldom that any floor is clear of blue-ground for many consecutive days; for the tipping of fresh material follows closely upon the removal of the old. Thus the floors-area, so far as vegetation is concerned, may be regarded as a small desert of blue-earth and rock, with here and there large mounds of the waste material from which the diamonds have been extracted. Kimberley extends along the southern boundary of this desert, and the village of Kenilworth (Griqualand West) touches it on its northern edge. Surrounding the whole is the virgin veldt of the country, consisting of thorn-bushes at intervals, and a coarse, starved-looking grass, with the red sand upon which it grows in evidence everywhere.

Now although the veldt is at best scarcely more than half-covered with vegetation, and the climate therefore as much influenced by the soil as by the vegetation upon it, yet it seemed *à priori* likely that the climate might be affected by the drastic clearance of such vegetation as there was, and also by the substitution of blue-ground for red over the floors. Such is the problem, and a solution of some of its leading aspects is attempted in this paper.

Relative Thermal Properties of Kimberlite and Red Sand.

The thermal properties of blue-ground as compared with red sand have first to be considered.

Two small patches, each about 30 inches square, were laid out side by side in the most exposed spot available, one of weathered, decomposed, virgin blue-ground, the other of red sand. These were made as level and smooth as possible. The depth of the deposit of blue-ground was about 3 inches, the space beneath and surrounding it being red sand. A mercurial Board of Trade thermometer was placed in the midst of the blue patch, the centre of its spherical bulb being almost exactly 1 inch beneath the surface, and another exactly similar and similarly situated in the centre of the red patch. These thermometers were both inclined at an angle of about 30° from the vertical for convenience in reading, and kept in place by a thin wooden prop behind. A thin wooden lath also covered each column and scale as a protection against possible hail and missiles. The readings were taken at VIII., XIV., and XX. civil time. A spirit radiation thermometer of the ordinary pattern was also placed in a horizontal position over each patch, and supported by the thinnest wooden forks strong enough to carry it, the centre of the spherical bulbs being almost exactly three-quarters of an inch above the surface. These were also read at VIII., XIV., and XX., and readings of the minimum were also taken as well. The experiment lasted from July 4th continuously till September 30, 1898, and may be regarded as including more or less all types of Kimberley weather. These were the best arrangements I was able to make for the purpose. There is no doubt, of course, that if larger patches could have been laid out, say each of 30 feet square, or better still, if simultaneous observations could have been taken, one set on the open veldt and the other in the midst of a depositing floor, better results must have been obtained. However, the figures given in Table I. will show the general tendency of the climatic effects of the two soils.

TABLE I.

Relative Thermal Properties of Blue-Ground and Red Sand. Mean Values.

A.—Radiation Temperatures at ¾ inch Above Surface.

1898.	Minimum.		VIII.		XIV.		XX.	
	Blue.	Red.	Blue.	Red.	Blue.	Red.	Blue.	Red.
	°	°	°	°	°	°	°	°
July 4th-31st........	23·7	22·9	29·9	29·5	66·9	65·7	35·1	34·2
August..............	32·7	30·2	42·6	40·8	84·9	83·1	46·1	43·2
September 1st–17th ..	35·3	32·1	47·8	46·0	89·2	85·7	50·5	47·3
September18th-30th..	39·5	37·1	60·5	61·2	93·8	91.4	54·8	51·5
July 4th–Sept. 17th ..	30·3	28·0	39·2	37·9	79·4	77·4	43·0	40·8

B.—Earth Temperatures at 1 inch Beneath Surface.

	VIII.		XIV.		XX.	
	Blue.	Red.	Blue.	Red.	Blue.	Red.
		°	°	°	°	°
July 4th–31st	33·0	31·8	63·1	65·3	42·4	40·6
August	44·3	43·5	81·7	83·7	55·9	53·3
September 1st–17th	50·4	49·5	90·1	91·8	61·9	59·1
September 18th–30th	60·8	62·2	100·0	101·3	69·8	66·3
July 4th–September 17th	41·6	40·7	76·7	78·8	52·2	49·9

C.—Comparative Elements of Influence.

	July. Hours.	August. Hours.	September. Hours.
Amount of Cloud (0–10) *	0·6	1·7	1·7
Duration of Sunshine †	298½=92%	297=86%	301¾=84%
Mean Maximum Air Temperature	65·6°	72·5°	78·0°
Mean Minimum do.	32·7°	38·5°	42·2°

* From observations taken at VIII., XIV., and XX. civil time. The mean amount of cloud for the year is about 2·5. At Cordoba it is 4·5, and at Adelaide 4·8.

† As recorded by the Jordan Photographic recorder. According to a paper recently published in the *Quarterly Journal of the Royal Meteorological Society* by Mr. R. Curtis, describing some comparative observations made in England between the sunshine recorded by this type of instrument and that by the standard Campbell-Stokes burning recorder, it is claimed that the latter records the greater amount. With a sky in which cumulus prevails this would always be the case, because the record of the burning recorder is not a series of points, but a succession of large overlapping images—isolated clouds thus not receiving their true and sufficient angular dimensions on the trace. The record of the photographic recorder, on the other hand, is a series of narrow transverse lines.

Previously to September 18th neither of the experimental patches had emerged from the morning shadow cast by some adjacent gum-trees at VIII. From that time until the end of the month the red patch was either in partial shadow or full sunshine at viii., while the blue was in shadow or partial shadow at the same time. For this reason the VIII. observations after that date are not to be taken in the comparisons, the rest of the observations being nevertheless quite trustworthy.

The general conclusions to be drawn from Table I. are:—

1. The air is always warmer above the surface of the blue-ground than it is above the red sand.

2. Beneath the surface the blue-ground is always warmer by night and cooler by day than the red sand.

3. Finally, blue-ground is the better reflector and therefore the worse absorber: heat passes less readily, in or out, across the bounding surfaces of its particles. The uniformly greater temperature of the air just above its surface is a reflection effect by day, and an effect of actual warming by contact and conduction during the night.

The soil of many of the gardens in and about Kimberley is little besides blue-ground taken from the waste material of the heaps of tailings. That they should often be so flourishing may be partly due to the more equable thermal properties of blue-ground. Of humus they have obviously not a trace to begin with. Fruit-trees generally blossom much earlier in the spring in Kimberley, which is built almost entirely on *débris* from the mines, than they do in Kenilworth, where there is not any of this material; and a certain succulent plant known locally as the wild tobacco develops more luxuriantly upon the tailing-heaps than it ever does upon the native sand. A mixture of red sand and blue-ground seems also to make a good soil for a garden.

Effects on Climate.

The great differences in the thermal properties of blue-ground and

encroaching very little into the spaces which should be left blank by clouds. It follows as a necessary consequence that the maximum amount of sunshine in the diurnal range is displaced too near to noon by the Campbell-Stokes instrument.

Clouds being relatively rare at Kimberley, it is doubtful if a Campbell-Stokes recorder of the very best construction could record more sunshine than the Jordan instrument. And here it may not be out of place to add that Kimberley is perhaps one of the most sunny places in the world. The mean sunshine for the year is about 76 per cent. of the greatest amount possible, Allahabad (India) having perhaps 70 per cent., Cordoba (S. America) 62 per cent., Adelaide (S. Australia) 60 per cent., and St. Aubin's (Jersey) 39 per cent.

red sand would make it almost certain that the climate of the vicinity must be materially affected by the considerable area of blue-ground exposed on the depositing floors. To test this I have compared the daily maximum temperatures of Kimberley and Kenilworth for the years 1894, 1895, and 1896, making use of 1,075 pairs of observations for the purpose. The Kimberley observations were kindly placed at my disposal by Mr. G. J. Lee,* F.R.Met.S., F.R.M.S.; the Kenilworth observations were taken by myself.

Table II. shows the mean differences of maximum temperatures, Kimberley *minus* Kenilworth, month by month for the three years. A *plus* sign indicates that the Kimberley temperature was the greater, a *minus* sign that it was less.

TABLE II.

Mean Differences between the Maximum Air Temperatures of Kimberley and Kenilworth.

	1894.	1895.	1896.	Mean.
	°	°	°	°
January	+2·7	+2·9	+5·8	+3·8
February	+1·1	+1·6	+4·9	+2·5
March	+0·6	+0·1	+3·0	+1·2
April	−1·7	−1·9	+0·3	−1·1
May	−2·2	−3·0	−0·5	−1·9
June	−2·7	−3·0	−0·8	−2·2
July	−2·4	−2·3	−1·1	−1·9
August	−1·2	−1·4	+0·3	−0·8
September	+0·6	+0·2	+2·0	+0·9
October	+0·6	+4·8	+5·1	+3·5
November	+3·8	+6·4	+6·9	+5·7
December	+2·4	+5·0	+6·8	+4·7

Some of the monthly differences are doubtless due to faults of exposure at both places. In September, 1895, the Kenilworth thermometers were transferred to a new, large, louvred screen, which, as tested by a slung thermometer, gave much more accurate results; the effects of radiation from the ground being largely, if not altogether, eliminated. The greater differences since that time are due to this alteration. The Kimberley thermometers were in the same position throughout the period. They were mounted under a somewhat modified Glaisher stand.

* Mr. Lee died in May last. Though not in any broad sense a meteorologist, yet he had taken regular climatological observations at his own second-order station for many years. Few men have had greater opportunities than he of amassing wealth, but the sordid pursuit of riches had for him no attractions. Living without ostentation, an earnest lover and devout worshipper of nature. Kimberley society scarcely knew of his existence; and Kimberley newspapers, characteristically, reported his death in grudging lines as that of a "local astronomer and weather-prophet"!

It is curious that the monthly differences in both December, 1894 and 1895, should be less than the November before and the January after, and in all probability the same thing would show in the mean results had there been no change of exposure at Kenilworth.

The numbers in the table would appear to indicate that the Kimberley days are warmer in summer and cooler in winter than those of Kenilworth. The great number of trees about Kenilworth may, perhaps, contribute something to this result; but it seems more likely to be due to an inherent defect in the Glaisher stand, however it may be modified: *i.e.*, to the utter lack of protection which it can afford against the effects of radiation from the ground in such a climate as ours. How effective radiation may prove as a source of error in temperature observations, unless properly guarded against, will be seen from Table III., wherein a comparison is made between the approximate maximum surface-soil temperature at a depth of 1 inch and the maximum temperature of the air.

TABLE III.

Mean Monthly Maximum Temperature of the Air at Kenilworth compared with the Mean Surface-Soil Temperature at 2 p.m.*

	Soil Temperature at 1 inch beneath Surface.		Monthly Maximum Temperature of the Air.		Differences.	
1897.	Mean at xiv. S	Greatest observed S′	Mean T	Absolute T′	S−T	S′−T′
	°	°	°	°	°	°
January ..	98·7	113·8	84·9	94·7	+13·8	+19·1
February ..	110·7	117·8	91·3	99·8	+19·4	+18·0
March	97·5	112·8	83·5	92·8	+14·0	+20·0
April	95·0	104·9	83·4	92·2	+11·6	+12·7
May	76·2	86·2	72·5	81·5	+ 3·7	+ 4·7
June	63·3	69·0	65·2	72·7	− 1·9	− 3·7
July	66·7	76·5	67·6	75·1	− 0·9	+ 1·4
August ..	80·9	88·2	73·0	83·3	+ 6·1	+ 4·9
September .	92·0	104·8	78·1	91·2	+13·9	+13·6
October ..	104·2	119·3	85·3	96·6	+18·9	+22·7
November .	110·3	123·7	86·4	100·6	+23·9	+23·1
December .	112·4	126·8	91·7	97·5	+20·7	+29·3
Means ..	92·3°		80·2°		+11·9°	
Extremes .		126·8°		100·6°		+26·2°

* In October, 1898, it was ascertained that the depth of the bulb of the thermometer with which these observations were made had increased from 1 inch to nearly 2 inches beneath the surface. This may be accounted for partly by an actual sinking of the thermometer, and partly by a possible accumulation of drift sand upon the site.

The tendency of these numbers is to show that the lower the temperature of the air the nearer does it approach the temperature of the ground. And doubtless if the temperature of the mathematical surface of the ground could be ascertained the effect would be still more marked.

It is obvious that if we wish to get a true idea of the relative temperatures of Kimberley and Kenilworth sources of error due to faults of exposure must, as far as possible, be allowed for. The method adopted after sundry trials was to consider the mean monthly error at both places to be a constant throughout any assigned month. And thus the mean difference *d* between the Kimberley and Kenilworth maximum temperatures for that month shall be a constant quantity, which, if applied with its proper sign to the Kenilworth maximum on any day in that month, will give the true relative difference for the same day between the maxima of the two places. The method answers equally well for the months before or after the change in the exposure of the Kenilworth thermometers. The process will be best understood by the annexed Table IV., representing a specimen month of readings in full.

In this table—

Column 1. Contains the dates.
,, 2. The direction of the wind at 2 p.m.
,, 3. The maximum air temperatures of Kimberley (K).
,, 4. The maximum air temperatures of Kenilworth (K′).
,, 5. The differences between the maxima of Kimberley and Kenilworth $(K - K')$ + or − according as $K >< K'$.
,, 6. The corrected differences (cor. $K - K'$) obtained from column 5 by applying to each of the differences shown in column 5 a correction equal to the mean value of column 5. For example: the mean value of column 3 in the table is 67·7°, and of column 4 is 68.2°. The mean difference $K - K'$ of these is −0·5°, which is manifestly the mean value of column 5. Deducting this quantity from each of the numbers in column 5 we get column 6, *i.e.* :—

$$-0{\cdot}3^\circ - (-0{\cdot}5^\circ) = +0.2^\circ$$
$$+0{\cdot}4^\circ - (-0{\cdot}5^\circ) = +0{\cdot}9^\circ$$

and so on.

These calculations were made for each month, and the numbers from column 6 then arranged into groups according to the direction of the wind. The derived mean monthly differences are shown in Table V.

TABLE IV.

Specimen Month of Comparative Maxima.

May, 1896.	Direction of Wind at XIV.	Maximum Temperatures.		Differences.	
		K	K′	K−K′	Cor. K−K′
		°	°	°	°
1	N.W.	76·9	77·2	−0·3	+0·2
2	W.N.W.	79·2	78·8	+0·4	+0·9
3	N.W.	78·3	78·0	+0·3	+0·8
4	N.W.	77·4	76·5	+0·9	+1·4
5	S.W.	61·0	60·5	+0·5	+1·0
6	S.S.W.	59·1	58·8	+0·3	+0·8
7	E.	64·4	65·5	−1·1	−0·6
8	N.	69·6	68·5	+1·1	+1·6
9	E.	66·2	67·0	−0·8	−0·3
10	E.N.E.	56·0	57·0	−1·0	−0·5
11	N.N.W.	63·4	65·0	−1·6	−1·1
12	S.W.	60·5	61·2	−0·7	−0·2
13	N.W.	65·0	66·5	−1·5	−1·0
14	N.N.W.	68·0	67·5	+0·5	+1·0
15	N.W.	70·2	70·8	−0·6	−0·1
16	N.N.W.	74·8	74·8	0·0	+0·5
17	S.	70·4	70·5	−0·1	−0·4
18	S.	67·6	67·8	−0·2	−0·3
19	S.	66·2	67·8	−1·6	−1·1
20	S.	67·1	68·0	−0·9	−0·4
21	W.S.W.	67·6	70·0	−2·4	−1·9
22	W.	70·6	70·8	−0·2	+0·3
23	N.W.	72·0	72·0	0·0	+0·5
24	W.	67·9	69·5	−1·6	−1·1
25	S.W.	59·9	60·8	−0·9	−0·4
26	S.E.	60·9	61·5	−0·6	−0·1
27	N.W.	66·0	67·0	−1·0	−0·5
28	S.	66·6	67·5	−0·9	−0·4
29	N.E.	68·4	68·8	−0·4	+0·1
30	N.N.E.	68·0	68·8	−0·8	−0·3
31	N.W.	68·1	69·2	−1·1	−0·6
Means .	..	67·7°	68·2°	−0·5°	..

Table VI. represents these means further arranged into quadrants; Quadrant 1 including all wind directions from N. to E.N.E., Quadrant 2 all from E. to S.S.E., Quadrant 3 all from S. to W.S.W., and Quadrant 4 all from W. to N.N.W.

Table VII. represents the same thing, excepting that quarters of a year are taken instead of months, and also that the number of times the wind was observed in any quadrant is added.

TABLE V.

Mean Monthly Corrected Differences of Maxima arranged according to the Direction of the Wind.

	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.	Means.
	°	°	°	°	°	°	°	°	°	°	°	°	°
N.	+1·03	+0·23	+0·17	+0·38	+0·48	+0·20	−0·30	+0·23	+0·48	+0·83	+0·08	−0·46	+0·31
N.N.E.	−1·71	+1·49	+0·15	+1·20	+0·23	+0·57	+0·20	+0·45	−0·15	−0·08	−0·63	+0·90	+0·14
N.E.	−0·40	0·00	−1·30	−0·34	+0·27	−0·23	−1·40	+0·10	−0·15	+1·10	−1·15	−1·27	−0·35
E.N.E.	−1·05	−0·70	+0·40	+0·50	−0·85	+0·70	−0·20	..	..	−1·17	−0·20	−2·40	−0·46
E.	+0·15	+0·02	−1·18	−0·44	−0·53	−0·67	−2·00	−2·45	−1·60	..	+1·20	+0·23	−0·40
E.S.E.	−2·90	−0·30	..	..	..	..	..	..	..	..	..	−0·40	−0·37
S.E.	..	−1·90	−4·40	..	−0·23	..	+3·50	..	..	..	+1·20	−0·60	−0·36
S.S.E.	−3·20	−1·12	+1·35	+0·80	−2·30	−1·00	−0·95	..	..	−1·85	−0·40	+0·60	−0·57
S.	−1·48	−1·46	−2·90	−0·78	−0·84	−0·62	−0·28	−1·00	−1·40	−1·50	−1·30	−0·95	−1·09
S.S.W.	+0·90	−0·50	+1·02	−0·65	+0·80	+0·16	+0·05	−0·50	−1·04	+0·34	−0·53	..	+0·08
S.W.	−3·10	..	−0·85	−0·18	−0·38	+0·33	+0·15	−1·50	−0·60	−0·30	+0·62	−0·47	−0·35
W.S.W.	−0·98	−0·90	−1·10	−1·15	−0·23	−0·15	+0·34	−0·71	−0·22	−0·72	−0·56	−0·38	−0·46
W.	+0·11	+0·59	+0·51	−0·19	+0·04	+0·13	+0·11	−0·02	−0·57	+0·08	−0·13	+0·35	+0·11
W.N.W.	+0·56	+0·05	−1·15	−0·22	−0·25	+1·17	−0·39	+0·02	+0·47	−1·07	+0·27	+0·48	−0·03
N.W.	−0·02	..	+0·52	+0·09	0·00	−0·24	−0·19	+0·11	+1·50	+0·45	+0·44	+0·28	+0·20
N.N.W.	+0·42	−0·19	+0·48	+0·46	+0·32	−0·34	+0·16	+0·30	+0·50	+0·47	−0·14	+1·47	+0·23

TABLE VI.

Mean Monthly Corrected Differences of Maxima arranged according to Quadrants.

	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.	Means.
	°	°	°	°	°	°	°	°	°	°	°	°	°
Quadrant 1	+0·13	+0·48	−0·06	+0·22	+0·31	+0·16	−0·30	+0·29	+0·23	+0·31	−0·33	−0·41	+0·12
,, 2	−0·65	−0·42	−0·91	−0·86	−0·66	−0·75	−0·10	−2·45	−1·60	−1·85	+0·40	+0·11	−0·44
,, 3	−0·50	−1·05	−0·61	−0·57	−0·51	−0·11	+0·10	−0·71	−0·58	−0·52	−0·36	−0·48	−0·47
,, 4	+0·17	+0·25	+0·33	−0·02	+0·06	−0·02	−0·04	+0·15	+0·34	+0·15	+0·01	+0·45	+0·15

TABLE VII.

MEAN MONTHLY CORRECTED DIFFERENCES OF MAXIMA ARRANGED QUARTERLY IN QUADRANTS.

	First Quarter.		Second Quarter.		Third Quarter.		Fourth Quarter.	
	Times Observed.	Mean Differences.	Times Observed.	Mean Differences.	Times Observed.	Mean Differences.	Times Observed.	Mean Differences.
		°		°		°		°
Quad. 1	93	+0·16	85	+0·24	59	+0·16	61	−0·16
,, 2	32	−0·58	18	−0·40	8	−1·06	19	−0·04
,, 3	39	−0·72	53	−0·37	62	−0·38	61	−0·47
,, 4	100	+0·26	109	+0·00	145	+0·14	131	+0·19
	264		265		274		272	

Table VIII. gives a yet more condensed grouping, arrived at by drawing an East and West line, and calling all winds which cross it with increasing latitude northerly (N.), and all which cross it with decreasing latitude southerly (S.), west winds being classed with the former and east with the latter. In other words, all winds of Quadrants 1 and 4 are N., and all of Quadrants 2 and 3 are S.

TABLE VIII.

MEAN MONTHLY CORRECTED DIFFERENCES OF MAXIMA ARRANGED QUARTERLY ACCORDING TO THE WIND'S INCREASE OR DECREASE OF LATITUDE.

	First Quarter.		Second Quarter.		Third Quarter.		Fourth Quarter.		Total.	
	Times Observed.	Mean Differences.	Times Observed.	Mean Differences.	Times Observed.	Mean Differences.	Times Observed.	Mean Differences.	Times Observed.	Mean Differences.
		°		°		°		°		°
N.	193	+0·21	194	+0·10	204	+0·14	192	+0·08	783	+0·14
S.	71	−0·66	71	−0·38	70	−0·46	80	−0·36	292	−0·49

The evident interpretation of Tables V., VI., VII., and VIII. is that northerly winds raise the temperature of Kimberley above the normal, whereas southerly winds do the same for that of Kenilworth. It must not be inferred, however, that the numbers given in these tables show absolutely by how much the maximum temperatures are modified by particular winds; that could only be determined if we knew what would be the temperatures if the floors did not exist. Not only that, but the iron roofs of the houses are much more liberally distributed in Kimberley than they are in Kenilworth, and this must also exert some influence. Yet considering how largely secondary influences enter into and disturb normal meteorological phenomena, it is perhaps surprising that the final results should develop with so much regularity.